ATF USER MEETING

High Gradient, High Field Dielectric Wakefield Acceleration Experiments @ATF

AE39 Experimental Report

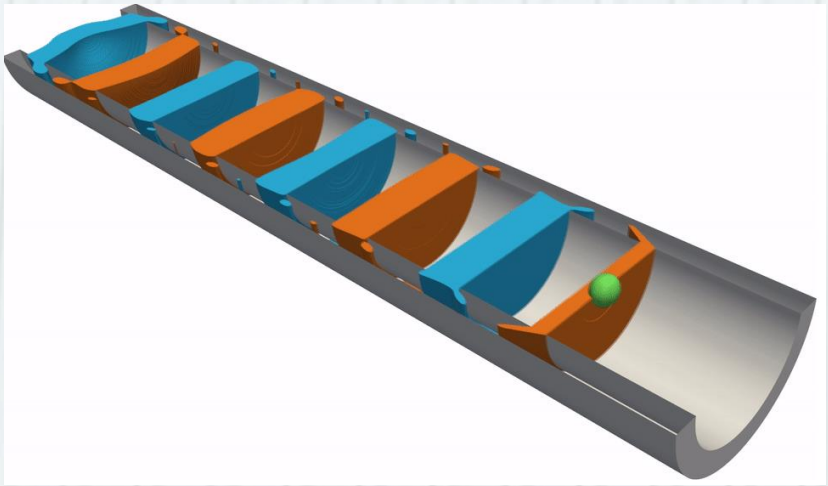
P. D. HOANG
PI: J.B. Rosenzweig
PARTICLE BEAM PHYSICS LAB
UCLA

Brookhaven National Lab
October 26th-27th 2016

Outline

- Dielectric wakefield acceleration (DWA)
  - Background
  - Some highlights
- AE39:
  - Previous DWA results
  - Transverse wakefield and slab-symmetry
  - Recent result on dielectric woodpile.
- Future outlook and summary

DWA in a Nutshell

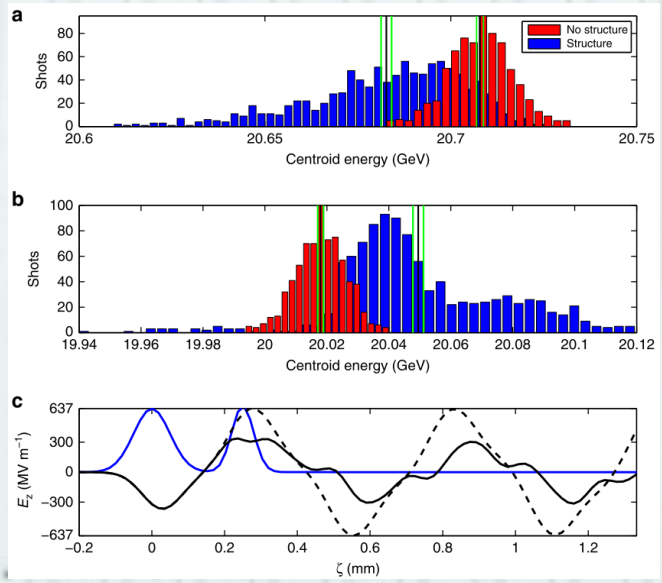


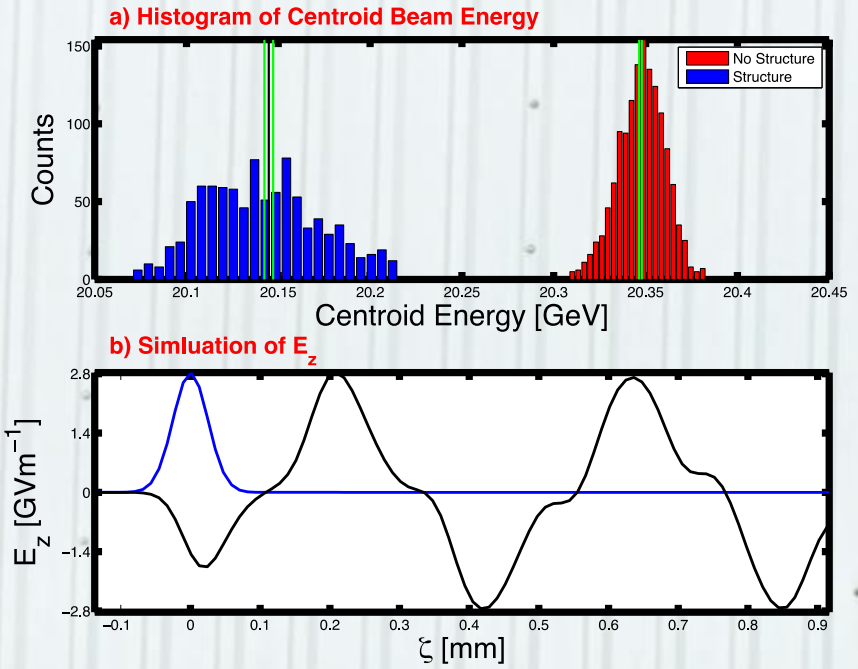
- Drive beam gives up its energy and sets up wakefield.
- Drive-witness modality. For $\beta \sim 1$, beam and wake stay in phase.
- Cherenkov radiation $\omega = \vec{k} \cdot \vec{v}$
- High gradient: simple scaling law $E_z \sim \frac{Q}{a\,\sigma_z}$

- DWA science has been growing over the years:
  - Coherent THz radiation source
  - High gradients: materials, fabrication
  - Transformer ratio: beam shaping
  - Transverse wakefield: beam breakup, trajectory kicks.
  - Advanced geometry: slab-symmetric, photonic crystals

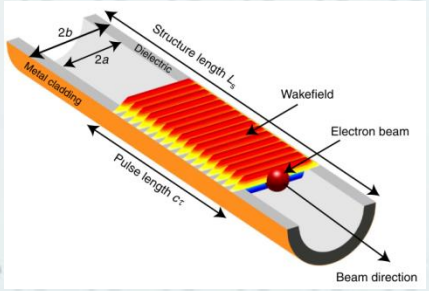
DWA Highlights

- DWA milestones:
  - Measure decelerating energy gradient of 1.347GeV/m. Inferred accelerating gradient ~2.8GeV/m
  - 80% drive-witness energy transfer
  - Structure robustness: 28 hours of contiguous operation or 100K pulses



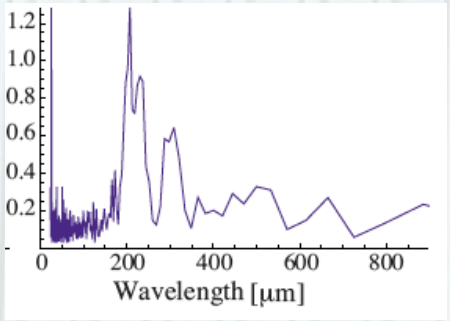


O'Shea , Nat. Comm., Vol. 7, 12763 (2016)
Experiment @ SLAC-FACET

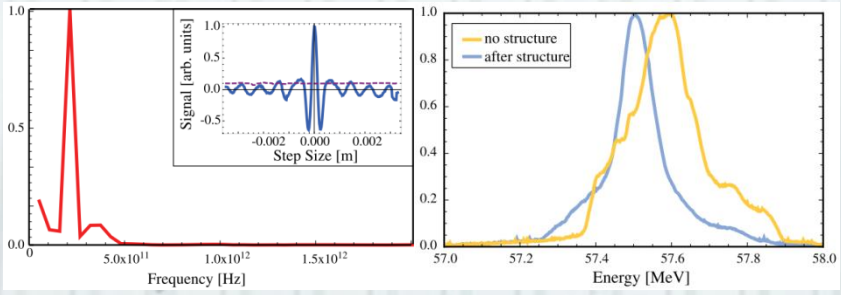


AE39: Previous Results

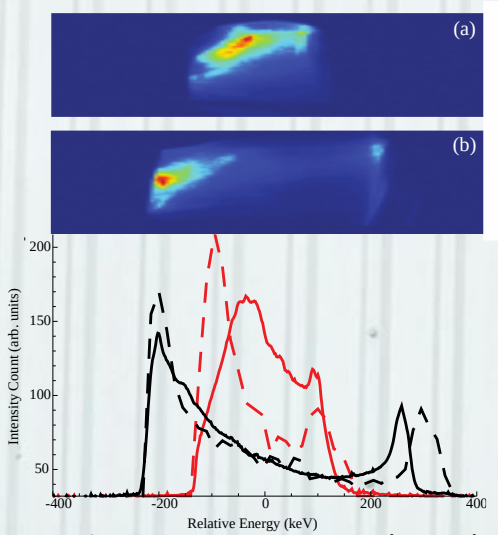
- **AE39 contributions to DWA science:**
  - **Andonian, APL 98, 202901 (2011)**
  - **Andonian, PRL 108, 244801 (2012)**
  - **Andonian , PRL 113, 264801(2014)**
  - **Hoang – Woodpile DWA in prep. (2016)**



G. Andonian et al., APL 98, 202901 (2011)
Selective mode excitation in tube @BNL ATF



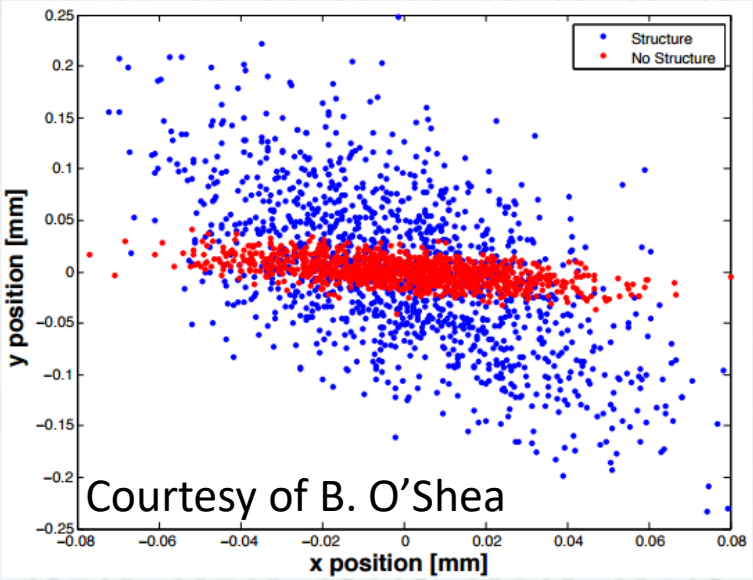
G. Andonian et al., PRL 113, 264801 (2014)
Narrow band THz and decc. from Bragg @ BNL ATF



G. Andonian et al., PRL 108, 244801 (2012)
Accel. in slab @ BNL ATF

Transverse Wake and Slab Symmetry

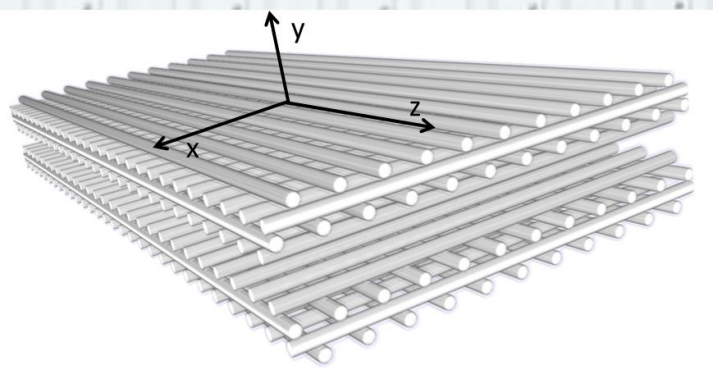
- Transverse deflecting wakes
  - Simple scaling law $E_{\perp} \sim \frac{Q}{a^3}$
  - Beam breakup instability, trajectory kicks
  - Need to be controlled for operation in long DWA structure.
  - Promising solution: slab-symmetric structure
- Slab-symmetric structures
  - Cartesian symmetry
  - Compatible with very small scale layer-by-layer fabrication
  - Deflecting kicks vanish in limit of infinitely flat beam[1]

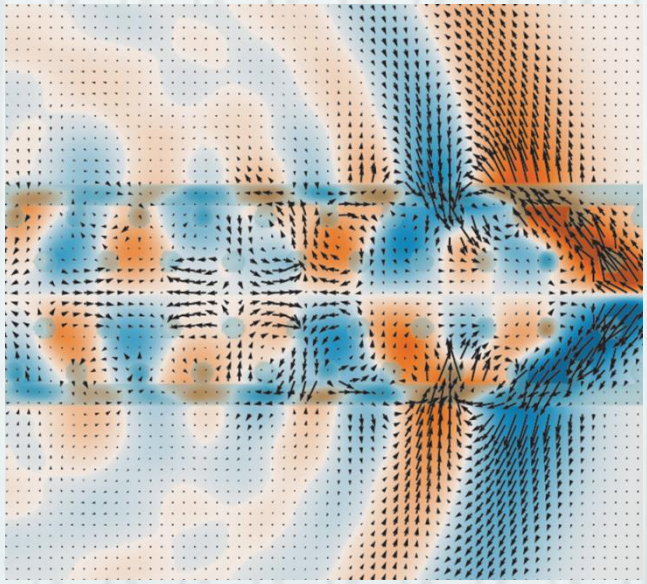


[1] A. Tremaine, et al., Phys. Rev. E 56, 7204 (1997)

AE39: Recent Experiment

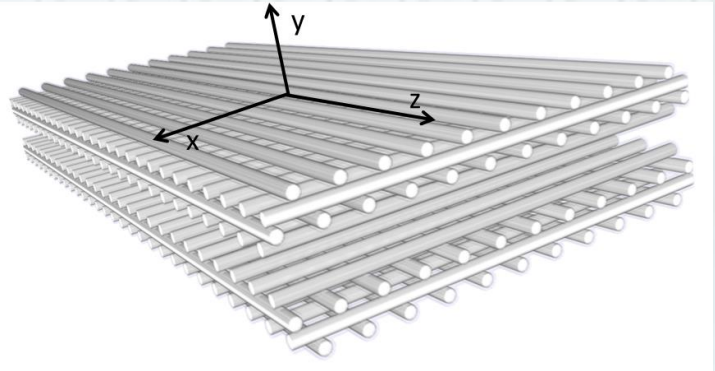
- Characterization of wakefield from dielectric woodpile structure
- Comparing wakefield spectra from round vs. flat beam
- See if we can observe transverse wakefield reduction

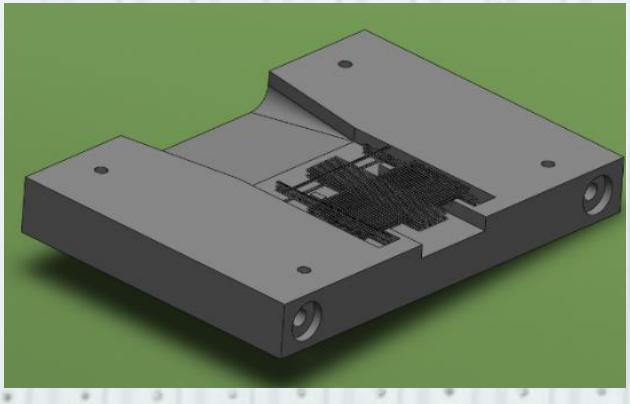


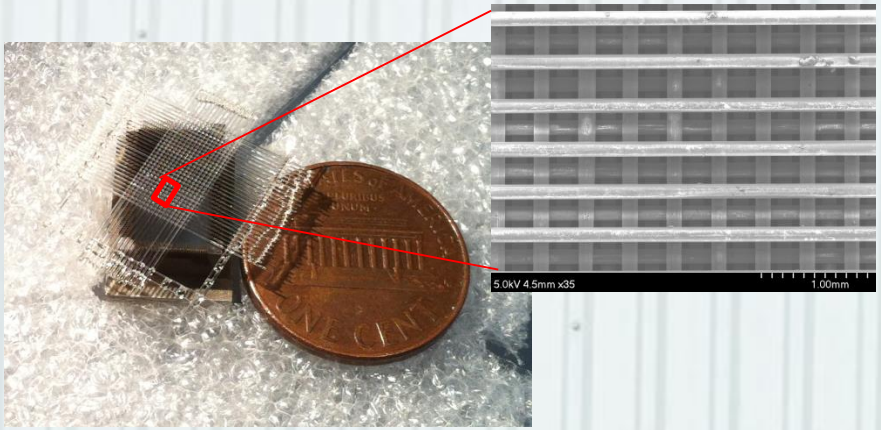


Dielectric Woodpile Structure

- Structure features
  - Slab symmetric
  - Metal free, expandable to 3D bandgap confinement structure.
  - Sapphire rods (125um), $\epsilon \approx 10$, high damage fluence.
  - Accelerating channel 250um
  - Round rods, $\frac{1}{\epsilon}$ field shielding factor.
  - Manual assembly

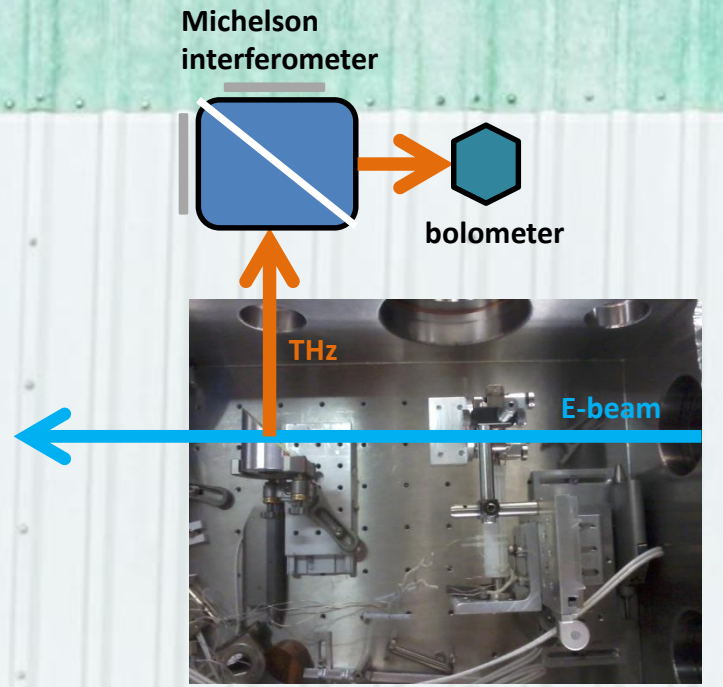




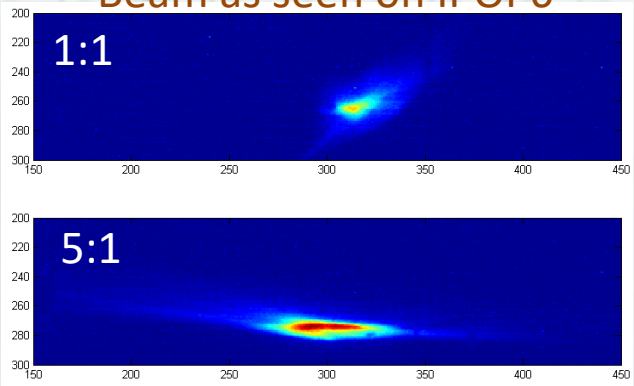


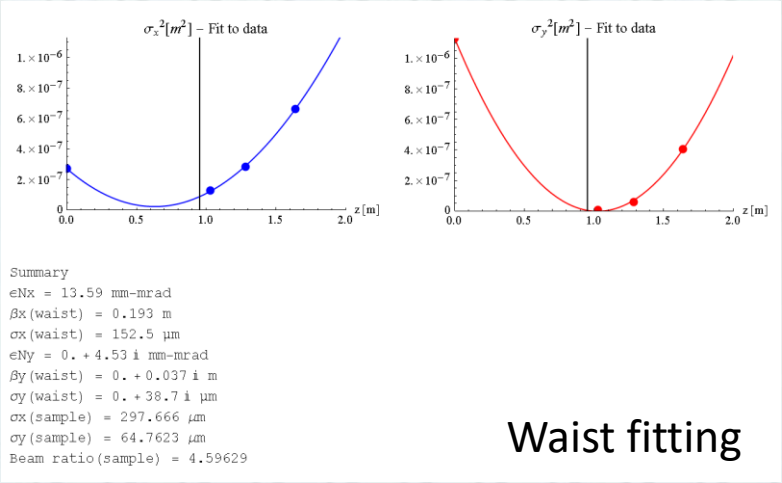
Woodpile Experiment

- HeNe laser and motorized stages for alignment
- Setup used Michelson interferometry + He-cooled bolometer
- Waist fitting to determine beam size
  - Round (1:1)
  - Wide (5:1)
- Bunch length $\sigma_z \approx 250\mu m$
- ~100% (200pC) charge transmission through structure
- Beam energy 57.6MeV



Beam as seen on IPOP6

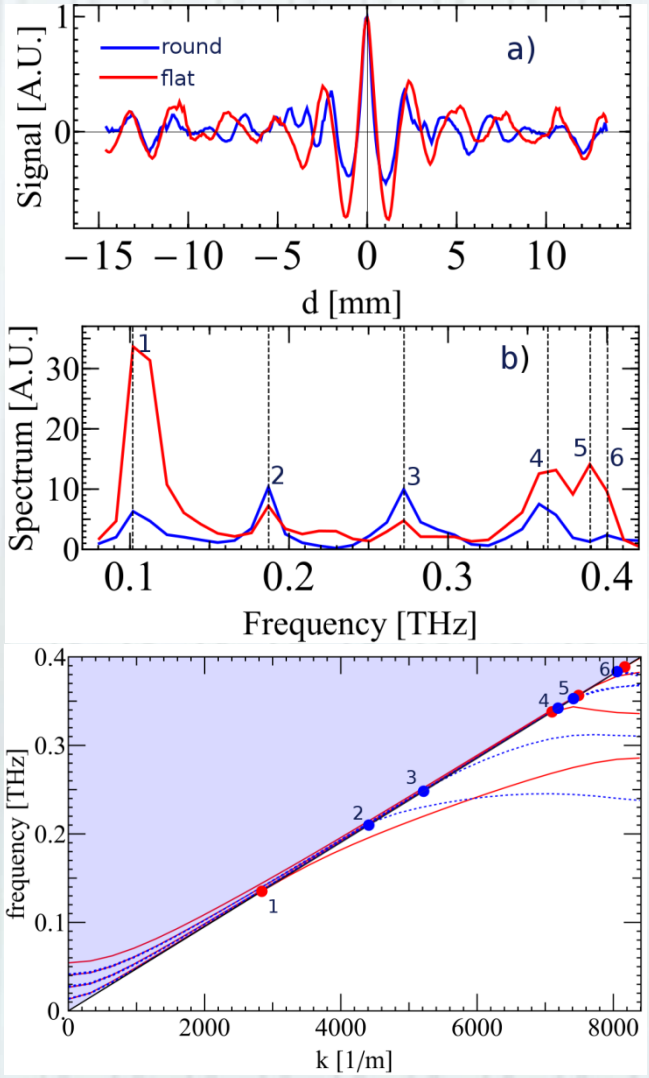




Waist fitting

Results to be Published

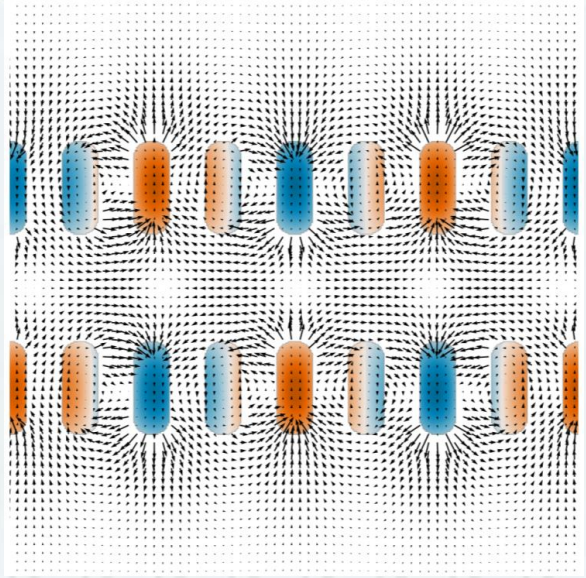
- Measured wakefield spectra driven by round/flat beam
- Match wakefield excitation pattern to eigen mode simulation which gives both frequencies and symmetries
- **Results: flat beam couples better to accelerating modes, and less efficiently to transverse modes. Agree with analytical prediction. In preparation for publication.**

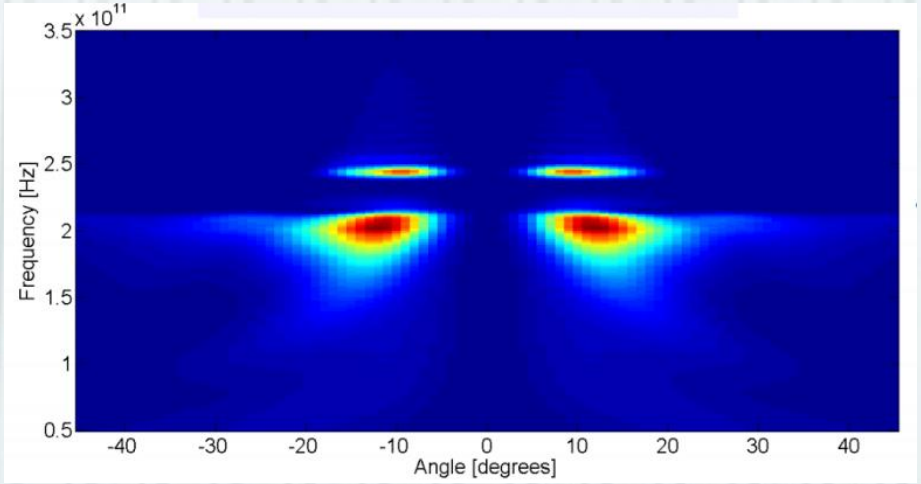


In prep. for publication

AE39 Future Plans

- Testing new structures with well established methods
- Wakefield characterization of scaled up DLA structure
  - Maxwell equations are scalable.
  - Easier fabrication
  - Availability of drive beam
  - Material studies
- Example: DIRNDL
  - Material SU-8
  - Modal characterization: excitation, far field imaging, etc.





Summary

- Wakefield mechanism capable of generating high accelerating gradient in compact scale.
- AE39 contribution:
  - THz radiation: selective excitation of modes
  - Demonstration of acceleration/deceleration in slab-symmetric structures
  - Novel photonic crystal based structure: Bragg structure
  - Newest result on woodpile structure directly addresses transverse wakefield reduction in slab-symmetric structure.
- Acknowledgement:
  - **BNL, ATF**: M. Fedurin, P. Jacob, K. Kusche, M. Polyansky, G. Sternby, C. Swinson, I. Pogorelsky, M. Palmer, I. Ben-Zvi
  - **UCLA**: G. Andonian, I. Gadjev, B. Naranjo, B. O'Shea (now SLAC),N. Sudar, Y. Sakai, O. Williams, J. Rosenzweig
  - **Office of Science**'s SCGSR program.